FERMILAB Conf-94/184-E
E769

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A. Wallace et. al
The E769 Collaboration

*Fermi National Accelerator Laboratory*
*P.O. Box 500, Batavia, Illinois 60510*

July 1994

Accepted by *ICHEP94*, July 20-27, 1994.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

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# Beam Flavor Dependence in the Hadroproduction of $D^{\pm}$ and $D_s^{\pm}$ Mesons

A. Wallace,[7] G.A. Alves,[1] S. Amato,[1,*] J.C. Anjos,[1] J.A. Appel,[2] J. Astorga,[5]
S.B. Bracker,[4] L.M. Cremaldi,[3] C.L. Darling,[7,†] R.L. Dixon,[2] D. Errede,[6,‡]
C. Gay,[4] D.R. Green,[2] R. Jedicke,[4,§] P.E. Karchin,[7] S. Kwan,[2] L.H. Lueking,[2]
J.R.T. de Mello Neto,[1,¶] J. Metheny,[5] R.H. Milburn,[5] J.M. de Miranda,[1]
H. da Motta Filho,[1] A. Napier,[5] D. Passmore,[5] A. Rafatian,[3] A.C. dos Reis,[1]
W.R. Ross,[7,∥] A.F.S. Santoro,[1] M. Sheaff,[6] M.H.G. Souza,[1] W.J. Spalding,[2]
C. Stoughton,[2] M.E. Streetman,[2] D.J. Summers,[3] S.F. Takach,[7,**] and Z. Wu[7]

(Fermilab E769 Collaboration)

[1] *Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil*
[2] *Fermi National Accelerator Laboratory, Batavia, IL 60510*
[3] *University of Mississippi, University, MS 38677*
[4] *University of Toronto, Toronto, Ontario, Canada, M5S 1A7*
[5] *Tufts University, Medford, MA 02155*
[6] *University of Wisconsin, Madison, WI 53706*
[7] *Yale University, New Haven, CT 06511*

June 14, 1994
ICHEP94 Contribution code: 0679

Fermilab E769, a fixed-target experiment conducted during the 1987-88 running period, yielded large numbers of charm particles. Through collisions of 250 GeV $\pi^{\pm}$, $K^{\pm}$, and p on a multifoil target, E769 allows for studies of beam flavor dependence in the hadroproduction of charm. Through the decay modes $D^+ \to K^-\pi^+\pi^+$, $D_s^+ \to \phi\,\pi^+$, and $D_s^+ \to \overline{K}^{*0}K^+$ (and charge conjugates), we have extracted $D^{\pm}$ and $D_s^{\pm}$ signals for all five beam types. We report preliminary measurements of the beam dependence of the absolute production cross-sections (for Feynman x $> 0$) of the $D^{\pm}$ and $D_s^{\pm}$.

QCD subprocess cross-sections for the creation of $c\bar{c}$ pairs in high-energy parton interactions have been calculated perturbatively up to next-to-leading order (NLO). Convolution of these with the quark and gluon distribution functions of mesons and baryons allows for calculation of the total rate of charm production in hadronic collisions [1]. Fragmentation to particular charm final states, however, cannot be treated perturbatively, thus complicating the calculation of hadroproduction cross-sections for charm particles. For example, enhanced production in the forward hemisphere of particles which share a quark with the projectile particle (the leading-particle effect) is a feature of some phenomenological models [2,3] and indeed has been observed at levels not attributable to the underlying perturbative process of charm quark production [4-6].

Fermilab experiment E769 has collected a data set well-suited to the study of these effects. About 400 million physics events were recorded at the Tagged Photon Spectrometer during the 1987-88 fixed target run. Electromagnetic and hadronic calorimetry provided the transverse energy trigger used to enhance the charm content of the set of events written to tape. A differential Čerenkov counter and transition radiation detector provided identification of the five 250 GeV secondary beam particles ($\pi^{\pm}$, $K^{\pm}$, and $p$), enabling studies of beam flavor dependence in charm production. Tracking and identification of charged secondary particles were achieved using an 11-plane silicon microstrip vertex detector, 2 analyzing magnets, 35 drift chambers, 2 multiwire proportional chambers, and 2 threshold Čerenkov counters.

In this paper we report preliminary results on the beam flavor dependence of $D^+$ and $D_s$ meson production cross-sections for $x_F > 0$. The $D^+$ sample was obtained through the decay $D^+ \to K^-\pi^+\pi^+$, the $D_s$ through the two decays $D_s^+ \to \phi\,\pi^+$ and $D_s^+ \to \overline{K}^{*0}K^+$. Throughout this paper charge conjugate decays are also implied.

Analysis cuts were chosen to optimize the statistical significance of Monte Carlo (FRITIOF 1.3, JETSET 6.3) signals over measured backgrounds. Invariant mass plots for the $D^+$ and $D_s$ for each of the five beam particles are shown in Figures 1a and 1b. Binned maximum likelihood fits using Gaussian signals and linear backgrounds were used to determine the number of events in each decay channel.

Acceptances were calculated from a Monte Carlo simulation of the experiment, which included the effects of the resolution, geometry, and efficiency of the spectrometer components, efficiencies associated with the event trigger and data acquisition system, and all analysis cuts. For each beam particle type, $D^+$ Monte Carlo events were weighted in $x_F$ and $p_T^2$ so as to match the measured distributions in these variables. Our preliminary measurements of the $D^+$ and $D_s$ production cross-sections are listed in Table 1. Errors quoted for the $D^+$ are statistical and systematic, in that order; only statistical errors are shown for the $D_s$. Branching fractions from the 1992 Review of Particle Properties [7] were used; their errors are not included.

Most previous measurements (see Figures 2 and 3, also Table 1) of $D^+$ and $D_s$ cross-sections have been obtained with $\pi^-$ and $p$ beams, although low-statistics $K^-$ beam results do exist [8-11]. E769 provides the first measurements of $\pi^+$ and $K^+$ induced charm meson production as well as significant additional measurements for $\pi^-$, $K^-$, and $p$ beams.

For both the $D^+$ and $D_s$, no significant differences in beam particle and antiparticle-induced cross-sections are observed. Also consistent with being equal are the $\pi$ and $K$ induced cross-sections, suggesting that the gluon distribution functions of the two mesons are similar. Additionally, we find that fragmentation of charm to $D_s$ is not greatly suppressed with respect to $D^+$ at this energy. In Figures 2 and 3, respectively, E769 results for $\pi^-$ and $p$ induced $D^+$ production are displayed alongside previous measurements. Assuming a constant $D^+$ fragmentation rate, the energy dependence of $D^+$ production can be compared to the theoretical predictions for all charm, as shown in the figures.

This research was supported by the U.S. Department of Energy, the U.S. National Science Foundation, the Brazilian Conselho Nacional de Desenvolvimento Científico e Technológico, and the Natural Sciences and Engineering Research Council of Canada.

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*Now at Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil.

†Now at Duke University, Durham, NC 27706.

‡Now at University of Illinois, Urbana, IL 61801.

§Now at LPL, University of Arizona, Tucson, AZ 85721.

¶Now at Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil.

‖Now at University of Oklahoma, Norman, OK 73071.

**Now at University of Cambridge, CB3 9EW, United Kingdom.

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Table 1: Forward $D^{\pm}$ and $D_s^{\pm}$ production cross-sections ($\mu$b/nucleon). Each given cross section is the sum of those for the final state particle and anti-particle. Errors quoted are statistical and systematic, in that order; only statistical errors are shown for E769 $D_s$ results. The following PDG 1992 branching fractions were used to obtain cross-sections from E769 measurements: $B(D^+ \to K^-\pi^+\pi^+) = (8.0\ ^{+0.8}_{-0.7})$ %, $B(D_s^+ \to \phi\,\pi^+) = (2.8 \pm 0.5)$ %, and $B(D_s^+ \to K^*K^+) = (2.6 \pm 0.5)$ %.

| Beam particle | $\sigma(BN \to D^{\pm}X,\ x_F > 0)$ | | $\sigma(BN \to D_s^{\pm}X,\ x_F > 0)$ | |
|---|---|---|---|---|
| ($B$) | E769 (preliminary) | Previous measurements | E769 (preliminary) | Previous measurements |
| $\pi^-$ | $3.8 \pm 0.3 \pm 0.2$ | see Figure 2 | $1.9 \pm 0.4$ | $1.7 \pm 0.3 \pm 0.3$ (ACCMOR NA32 @ 230 GeV) |
| $\pi^+$ | $3.9 \pm 0.4 \pm 0.4$ | | $2.9 \pm 0.9$ | |
| $K^-$ | $2.8 \pm 0.5 \pm 0.8$ | $4.1 \pm 1.0 \pm 0.3$ (ACCMOR NA32 @ 200 GeV) | $3.5 \pm 1.3$ | $2.8 \pm 1.5 \pm 0.5$ (ACCMOR NA32 @ 230 GeV) |
| $K^+$ | $3.1 \pm 0.4 \pm 0.4$ | | $2.8 \pm 1.1$ | |
| $p$ | $2.9 \pm 0.4 \pm 0.2$ | see Figure 3 | $< 1.9$ (90% C.L.) | |

Fig. 1a. Invariant mass distributions for $D^+ \rightarrow K^-\pi^+\pi^+$ (+ c.c.).

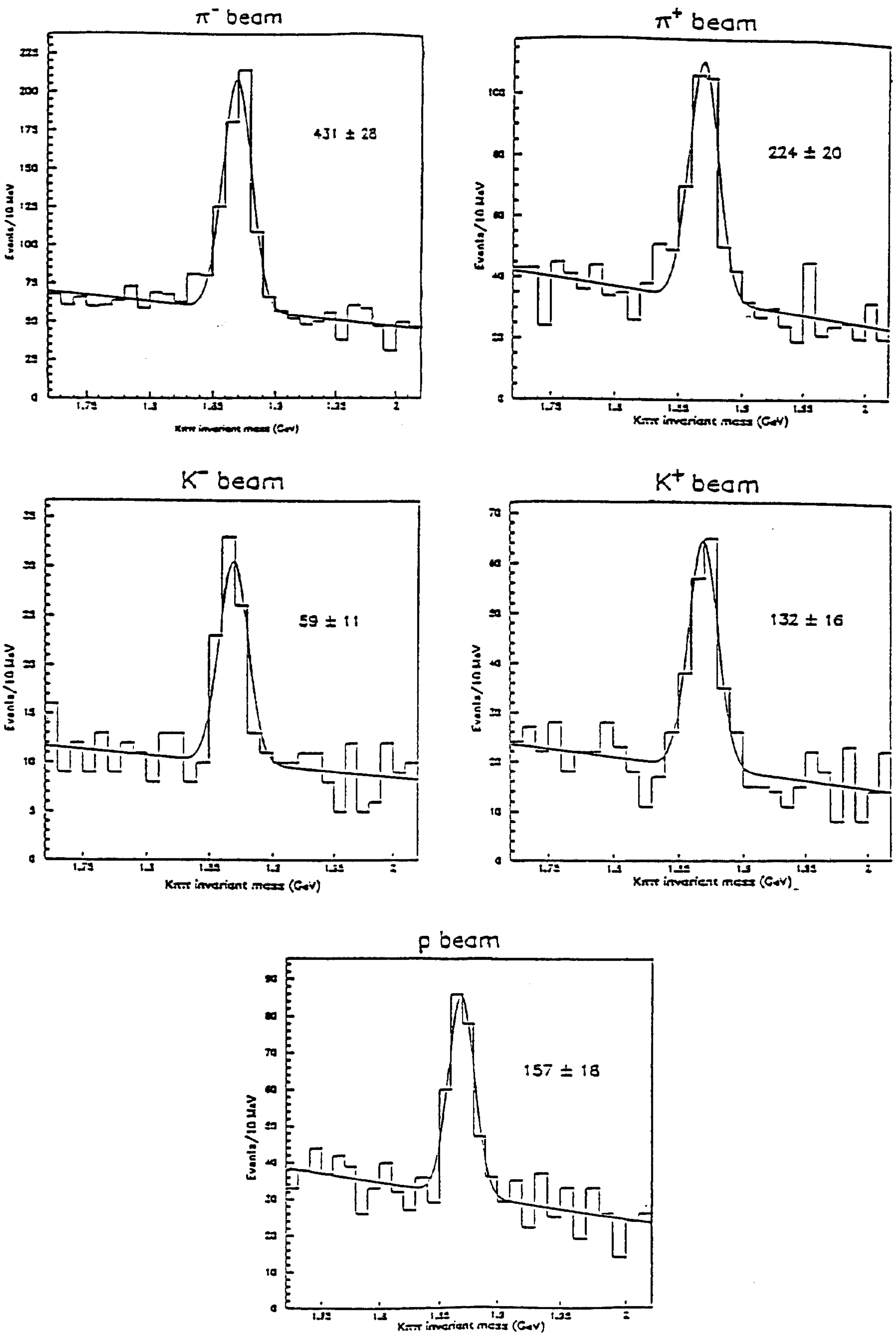

Fig. 1b. Invariant mass distributions for $D^+, D_s^+ \rightarrow \varphi\pi^+$ or $\overline{K}^{*0} K^+$ (+ c.c.).

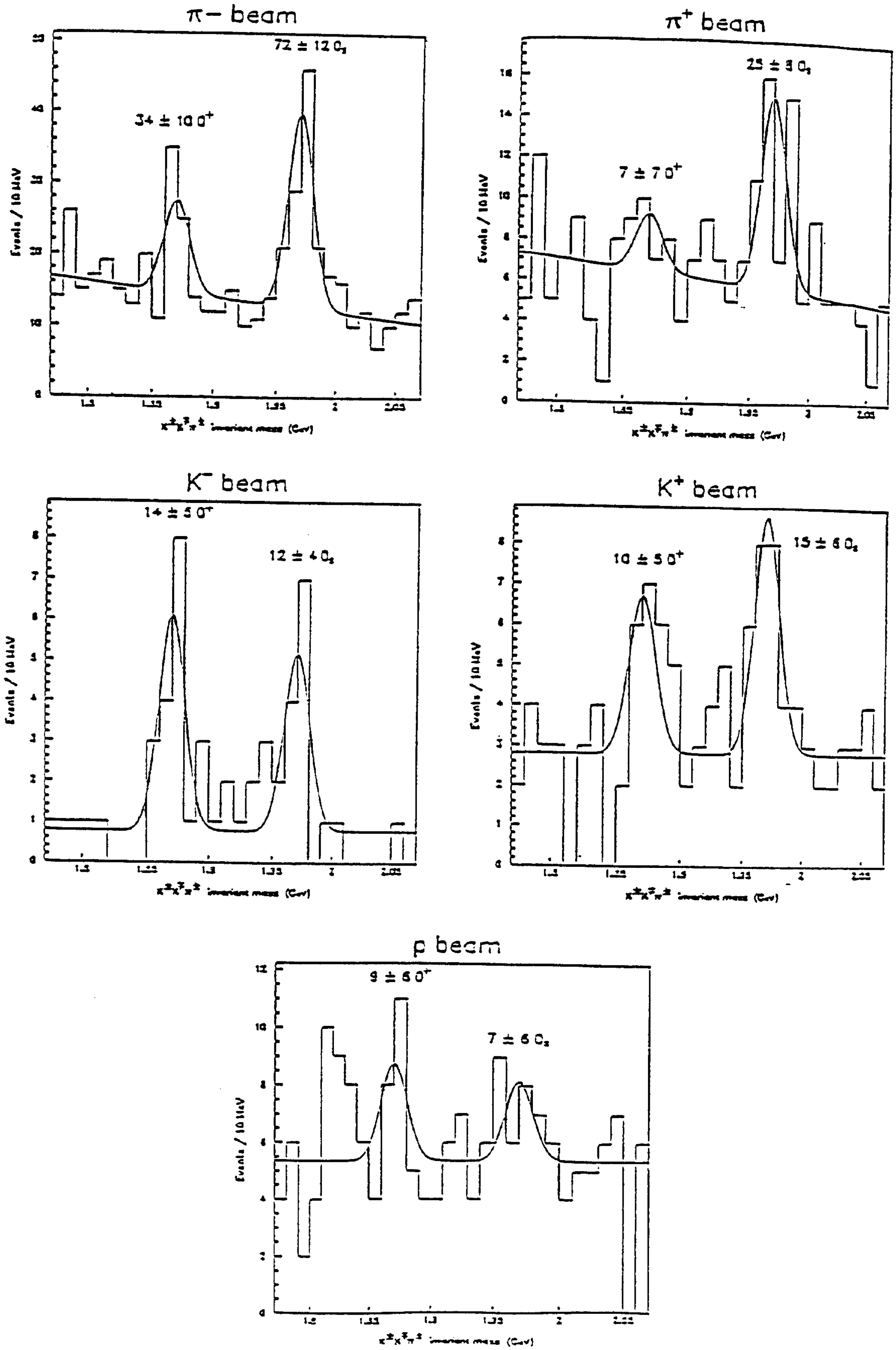

Fig. 2. Measurements of $\sigma(\pi^- N \to D^{\pm} X, x_F > 0)$.

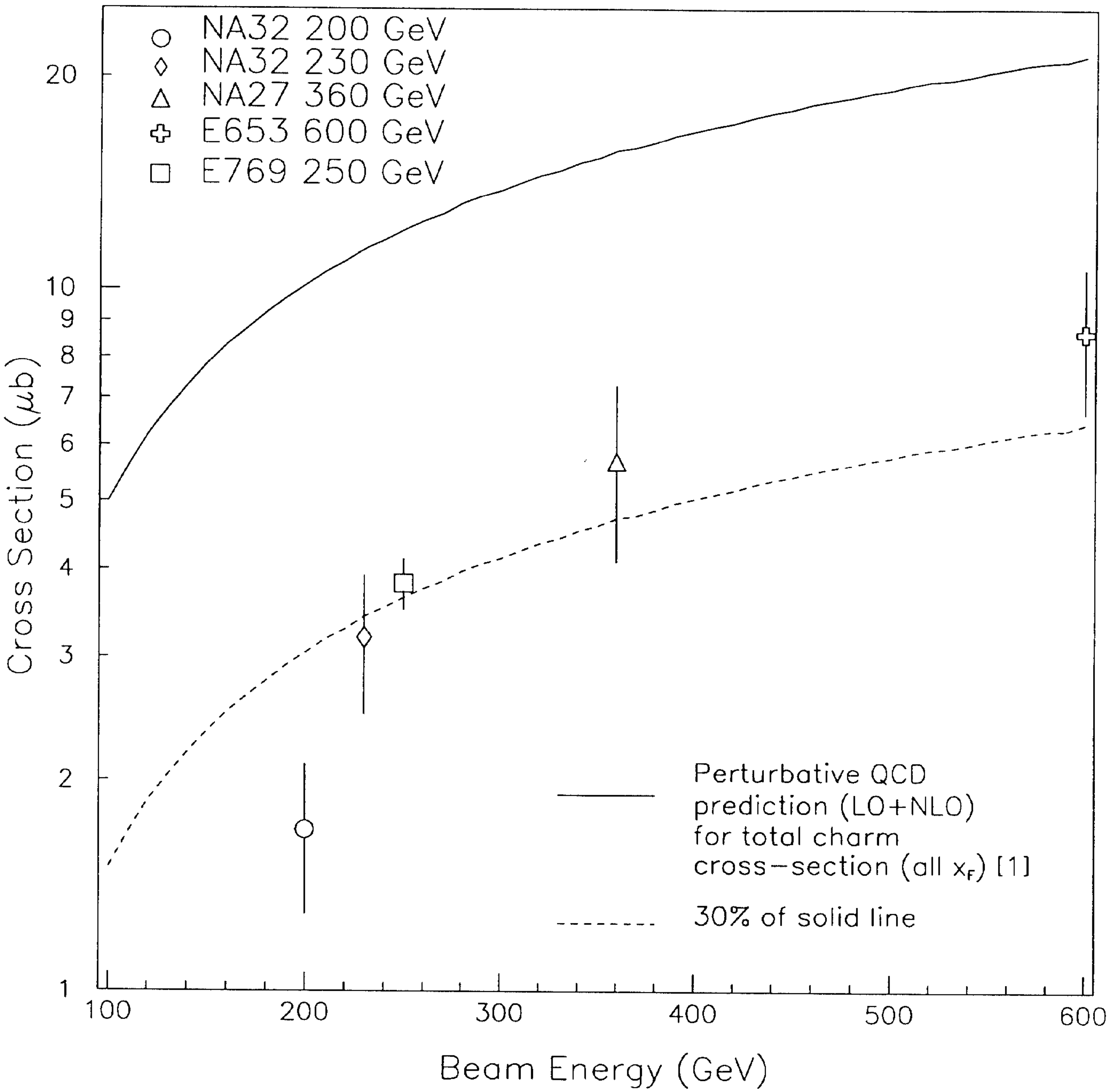

**Fig. 3.** Measurements of $\sigma(pN \rightarrow D^{\pm}X)$. E769 result is for $x_F > 0$; Other cross-sections shown are 50% of results for all $x_F$.